IFR Journal of Medicine and Surgery

eISSN: 3078-5456
pISSN: 3078-5448

Journal URL: https://ifrdiscovery.org/journal/IFRJMSS46

Publisher: International Federation of Research and Discovery

Address: Building No. 7, Dahiat Al-Rasheed-Borda Street, Amman, Jordania, 11831

ARTICLE TYPE: Review Article

Ankle Impingement Arthritis in Athletes: A Review of Mechanisms, Diagnosis, and Emerging Therapies

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How to cite:
Ali, M. J., Khan, A. A., Zhang, K., Dai, X., Zhu, Y., & Qin, J. (2025). Ankle impingement arthritis in athletes: A review of mechanisms, diagnosis, and emerging therapies. *IFR Journal of Medicine and Surgery, 2*(1), 1-8. https://doi.org/10.70146/msv02i01.001

DOI: 10.70146/msv02i01.001

Received: 19-02-2025	Accepted: 28-02-2025	Revised: 10-03-2025	Published: 20-03-2025

Abstract: ***Background:*** Ankle impingement arthritis is a common pathology, represented by chronic pain, stiffness and/or restrictions in range of motion due to soft tissue or bony entrapment within the joint. This is common in athletes or those with antecedent of repetitive trauma, resulting in functional impairment and progressive loss of joint function. ***Objective:*** Here, we seek to review this condition, focusing on its pathophysiology, clinical manifestations, diagnosis, and treatment. We discuss several recent advances in minimally invasive techniques, biologic therapies, and biomechanical innovations. ***Methods:*** Therefore, we performed a systematic review of the literature in order to update the knowledge regarding the clinical presentation, diagnostic modalities and treatment options of various syndromes such as the anterior, posterior, anterolateral, anteromedial and posteromedial) ankle impingement syndromes. ***Results:*** Ankle impingement is usually diagnosed by a combination of clinical examination findings and imaging modalities, including radiography, MRI, CT, and ultrasound. First-line includes conservative management with physical therapy, NSAIDs, and intra-articular injections; however, resistant cases require surgical intervention. Recent developments in arthroscopy, PRP therapy, and motion analysis may lead to enhanced joint retention and greater function. ***Conclusion:*** A multi-disciplinary method for the diagnosis and treatment of ankle impingement arthritis is vital for enhancing patient outcomes. Further investigation is warranted towards optimizing biologic modalities, minimizing surgical invasiveness, and incorporating wearable technology for personalized rehabilitation paradigms.

Keywords: Ankle impingement, arthritis, joint pain, arthroscopy, PRP therapy, diagnostic imaging, rehabilitation, sports injuries.

1. INTRODUCTION

Ankle impingement arthritis is a cause of pain and limited motion due to an impingement of osseous or soft tissue structures in the ankle joint [1]. It frequently occurs in athletes or people with repetitive insecure ankle motion [2], and results in chronic pain and functional limitations. Knowledge of the

etiology, clinical presentation, diagnostic modalities and treatment options is key to successful management.

The complex structure of the ankle joint and the high-demand conditions on it during weight-bearing activities predispose it to differenct types of impingement syndromes [3]. These syndromes are usually grouped according to anatomical classification: anterior, anteromedial, anterolateral, posterior, and posteromedial impingements, all presenting with different clinical features that need to be diagnosed and managed adequately [4].

This review will cover aspects of ankle impingement arthritis, describing its symptoms, the diagnostic tests required, and treatment options available. Through exploring the existing literature and clinical practices, we seek to provide further background information to assist clinicians with the identified condition [5].

2. Symptoms and Clinical Presentation

Ankle impingement arthritis presents with a spectrum of symptoms that vary based on the type and severity of impingement. The hallmark symptom is chronic pain localized to the anterior, posterior, or lateral aspect of the ankle, often exacerbated by dorsiflexion or plantarflexion movements [6]. Patients frequently report stiffness, swelling, and a sensation of blockage or catching within the joint, particularly after prolonged activity [7].

2.1 Types of Impingement and Associated Symptoms

1. **Anterior Impingement:** Also known as "footballer's ankle," this type is commonly observed in athletes and results from repetitive dorsiflexion trauma [8]. Symptoms include pain at the front of the ankle, reduced range of motion, and discomfort during activities such as running, squatting, or stair climbing [9].
2. **Posterior Impingement:** Often seen in ballet dancers and individuals involved in activities requiring forced plantarflexion, such as jumping sports [10]. Patients experience deep posterior ankle pain, particularly when pushing off the foot, and may report tenderness along the Achilles tendon or os trigonum region [11].
3. **Anterolateral Impingement:** Occurs due to soft tissue entrapment following ankle sprains, leading to synovial thickening and scarring [12]. Presents as persistent lateral ankle pain, instability, and a sensation of pinching during eversion and dorsiflexion [13].
4. **Anteromedial and Posteromedial Impingement:** Less common but typically related to repetitive trauma or previous ligamentous injury [14]. Medial-sided ankle pain with clicking or catching sensations, particularly with forced movements [15]. **Seen in Table 1.**

Table 1: Types of Ankle Impingement and Symptoms

S.no	Type of Impingement	Causes	Common Symptoms	Affected Population
1	Anterior	Repetitive dorsiflexion, bone spur formation	Pain in anterior ankle, limited dorsiflexion	Athletes (football, runners)
2	Posterior	Forced plantarflexion, os trigonum syndrome	Deep posterior ankle pain, worsens with plantarflexion	Ballet dancers, gymnasts
3	Anterolateral	Post-traumatic synovitis, chronic ankle sprains	Persistent lateral ankle pain, instability	Individuals with chronic ankle sprains
4	Anteromedial	Recurrent trauma, deltoid ligament injury	Medial ankle pain, clicking or catching	Patients with previous deltoid ligament injuries
5	Posteromedial	Posterior tibial tendon dysfunction, chronic instability	Posteromedial ankle pain, worsens with inversion	Individuals with chronic instability

2.2 Effect on Mobility and Quality of Life

Chronic ankle impingement progresses to functional impairment that can limit both normal activity and athletic performance. The ability to walk on uneven surfaces, stand for long periods or partake in high-impact sports is limited in many patients [16]. Unmanaged cases evolve over the years, leading to degenerative changes that additionally impair joint stabilization and function [17].

3. Diagnostic Tests and Imaging

Ankle impingement arthritis is diagnosed using a combination of clinical examination and imaging studies. A comprehensive workup can help categorize different impingement syndromes and other ankle pain disorders, including osteochondral lesions or ligamentous injuries [18].

3.1 Clinical Examination and Special Tests

A thorough physical examination is key in determining the most likely type (dishump) and location (dorsum, labrum, neck) of impingement. Common clinical tests include:

a) **Forced Dorsiflexion Test / Anterior Impingement Test:** The patient actively dorsiflex ankle with the examiner applying pressure on the front of the joint. A positive test causes pain and indicates anterior impingement [19].
b) **Posterior Impingment Test:** The examiner passively plantarflexes the ankle while applying a compressive force to the posterior talus. Posterior impingement pain is typically seen with os trigonum syndrome [20].
c) **Anterolateral Impingement Test:** The patient is in forced dorsiflexion and eversion and the examiner palpates the anterolateral ankle. Pain and crepitus produced during reproduction would suggest soft tissue impingement related to thickening of the synovial.
d) **Medial Impingement Test:** When the individual has forced inversion and plantarflexion, pain is produced along the medial aspect of the ankle. Indicates anteromedial or posteromedial impingement, common in chronic instability, [22].

3.2 Imaging Modalities

a) Radiography (X-ray): Standard anteroposterior (AP), lateral, and oblique images can reveal bony osteophytes, joint space narrowing, and osseous spurs characteristic of impingement [23]. Stress radiographs can be helpful for evaluating mechanical instability.
b) MRI: Most useful in identifying soft tissue impingement, synovial thickening, ligamentous injuries, and early cartilage degeneration [24]. Crucial to distinguish impingement syndromes from osteochondral defects or tendinopathies.
c) Radiographic Imaging for Identification of Joint Structures: CT Image quality, allows imaging of bony abnormalities (e.g. osteophytes, ossicles, and incongruity in joints) [25]. Typically utilized preoperatively (especially helpful for surgical planning with substantial bony impingement).
d) Ultrasound (USG): Helpful in dynamic evaluation of soft tissue impingement, particularly in anterolateral impingement [26]. Guides therapeutic injections and measures response.

4. Treatment Modalities

Most treatment of ankle impingement arthritis is guided by the severity of symptoms, underlying pathology, and the degree of joint damage. Approaches for treatment vary from conservative therapy to surgical intervention in refractory cases [27].

4.1 Conservative Management

Non-operative management is the first line in all but mild to moderate cases. It emphasizes alleviating symptoms and regaining ankle function.

4.1.1. Activity Modification and Rest: Reduction in activities that worsen symptoms such as repetitive dorsiflexion or plantarflexion movements may alleviate pain and avoid further damage to the joint [28].

This PRO has shown good internal validity and reliability for the measure of symptoms and function of the ankle and foot [26]. Physical Therapy (PT): A structured PT program aimed at improving ankle mobility, strengthening, and proprioceptive area allows for improved functioning of the joint and reduced pain [29]. This can be especially valuable in cases related to chronic instability [30].

4.1.2. Nonsteroidal Anti-Inflammatory Drugs (NSAIDs): Oral NSAIDs (such as ibuprofen or naproxen) manage pain and inflammation, especially during acute flare-ups [31].

Corticosteroid Intra-Articular Injections: These injections can provide temporary relief by decreasing inflammation in conditions with soft tissue impingement [32]. However, multiple injections are not recommended due to potential cartilage damage and joint deterioration [33].

Bracing and Orthotics: Ankle braces and orthotic devices can provide joint stability, especially in cases of ligamentous laxity or chronic instability (34).

4.2. Surgical Management:

Surgery may be required in cases where conservative treatment options are unsuccessful and an ongoing pain or functional limitation is a significant impairment to quality of life of the patient [35].

a) **Arthroscopic Debridement:** The most common surgical approach is arthroscopic debridement, which entails resection of bone spurs that cause impingement, as well as inflamed synovial tissue or scar tissue [36]. Being a minimally invasive method, with reduced recovery periods and good functional results [37].
b) **Open Excision of Bony Impingement:** In cases with significant osteophyte formation or joint degeneration, we may need to perform open surgery to excise large impinging structures [38].
c) **Ligament Repair or Reconstruction:** Patients with concomitant chronic instability may need ligamentous repair or reconstruction for joint stabilization and reduction of recurrent impingement [39].
d) **Ankle fusion or replacement:** In the end-stage cases with advanced arthritis, the definitive treatment is either ankle arthrodesis (fusion) or total ankle replacement (TAR) [40]. **Seen in Table 2.**

Table 2: Treatment Modalities Comparison

S.no	Treatment Type	Indications	Examples	Effectiveness	Recovery Time
1	Conservative	Mild to moderate cases, first-line treatment	Rest, PT, NSAIDs, corticosteroid injections	Good for early-stage impingement, prevents progression	Varies; 6-12 weeks with PT
2	Surgical	Severe impingement, refractory to conservative therapy	Arthroscopic debridement, ligament repair	High success rate in improving function and pain	3-6 months depending on procedure

4.3 Postoperative Rehabilitation and Outcomes

Postoperative rehabilitation following thoracotomy is crucial for the recovery success. Most patients are told to weight bear as tolerated based on the activity the surgeon has decided on [41]. The time for patients to get back to their sports and daily activities is typically 3–6 months after arthroscopic debridement, but it can take longer after open procedures [42].

Recent Developments and Future Perspectives: Recognizing different types of ankle impingement arthritis and growing knowledge and experience have expanded the arsenal to address ankle impringement arthritis through emerging treatment modalities, surgical techniques, and rehabilitation strategies. These innovations are expected to improve patient outcomes, decrease complications, and favor joint preservation [43].

5.1. Noval Non-Invasive Therapies

a) Platelet-Rich Plasma (PRP) and Biologic Injections PRP therapy: Is now recognized for its role in reducing inflammation and promoting tissue healing in patients with soft tissue impingement [44]. Initial studies indicate that intra-articular PRP injections may offer longer-lasting relief from pain compared to corticosteroids, especially in the early stages of cartilage degeneration [45]. Other biologics undergoing research include stem cell therapy and hyaluronic acid injections, which have potential to stimulate regenerative effects on damaged joint structures [46].

b) Shockwave Therapy: Extracorporeal shockwave therapy (ESWT) has been investigated as a non-invasive strategy to manage chronic impingement-related pain through enhanced tissue healing and decreased inflammation [47]. The role of arthroscopic derangement of the ankle in impingement is

still under investigation; however, early data are encouraging with regard to pain relief and improvement in mobility [48].

5.2 Improvements in Surgical Technique

Advancements in Arthroscopic Techniques:

a) Minimally Invasive and Augmented Arthroscopy: Over the span of time, there has been great improvement in the arthroscopic techniques, as compared to the earlier ones [49]. The advent of high-definition imaging and 3D navigation systems has improved the accuracy of bony impingement resections and ligamentous repairs [50]. Further technological improvements related to surgical accuracy and outcomes are the robotic-assisted arthroscopic techniques [51].

b) Biologic augmentation: The use of biologic scaffolds and growth factors adjunctively with arthroscopic surgical repair has been investigated to improve healing and prevent recurrent impingement [52]. Collagen-based implants [53] and tissue-engineered grafts [54] are being studied to enhance post-surgery ligament [55] and cartilage regeneration [56], respectively.

5.3Innovations on Gait Analysis and Biomechanics

a) Wearable Sensors and Motion Analysis: Wearable motion sensors and gait analysis tooling provide new information about potentially pathological biomechanical anomalies in terms of ankle impingement [54]. This real-time movement data supports clinicians in designing customized rehabilitation programs [55].

b) Innovative Pressure-Based Ortho-Insoles Designs and 3D-Computational Redevelopment: Smart insoles, i.e., 3D-printed orthotics and ortho-insoles comprising pressure sensors for optimizing load distribution while alleviating excessive stress in the joints of patients with chronic impingement and/or rehabilitation treatment of arthroplasty [56].

6. Opportunities and Gaps in Future Research:

a) Long-Term Outcomes of Biologic Therapies: Although biologic therapies (eg, PRP, stem cell therapy) are promising, long-term data on their effectiveness in preventing disease progression is lacking [57].

b) Personalized Medicine Strategies: Either genetic profiling or molecular markers have shifted in their scope, and hold the potential of identifying the population of patients likely to benefit the most with specific treatment strategies paving the way for a personalized management approach [58].

c) Preventive Strategies in High-Risk Groups: Longitudinal screening programs of athletes and patients with recurrent ankle injury could facilitate screening of at-risk individuals for early development of impingement arthritis and initiation of preventive measures [59].

7. CONCLUSION

Ankle impingement arthritis is a complex condition that results from repetitive trauma, joint degeneration, and soft tissue or bony entrapment within the ankle joint. It presents with progressive pain, stiffness, and functional limitations, significantly affecting an individual's mobility and quality of life. Early diagnosis is essential to prevent long-term complications, and a combination of clinical examination and imaging modalities provides accurate identification of the type and severity of impingement.

Treatment strategies range from conservative management, including activity modification, physical therapy, NSAIDs, and intra-articular injections, to surgical interventions such as arthroscopic debridement and ligament reconstruction for refractory cases. Advances in biologic therapies, minimally invasive techniques, and biomechanical innovations offer promising new treatment avenues that may enhance recovery and long-term joint preservation.

Despite these advancements, research is still needed to establish long-term outcomes of regenerative therapies, optimize personalized treatment approaches, and develop preventive strategies for high-risk individuals, particularly athletes and patients with chronic instability. Future studies should focus on integrating wearable technology, 3D-printed orthotics, and robotic-assisted surgical techniques to refine treatment protocols and improve patient outcomes.

By understanding the pathophysiology, diagnostic methods, and latest treatment advancements, clinicians can provide targeted management strategies that enhance functional recovery and reduce the burden of ankle impingement arthritis on affected individuals.

Conflicts of Interest: The authors declare no conflicts of interest.

Author Contributions: Conceptualization, Abdul Aleem Khan and Mohammed Junaid Ali; Data curation, Abdul Aleem Khan, Kaibin Zhang, Xiangyang Dai and Yiran Zhu; Formal analysis, Abdul Aleem Khan and Kaibin Zhang; Supervision, Jian Qin; Validation, Jian Qin; Writing – original draft, Abdul Aleem Khan; Writing – review & editing, Abdul Aleem Khan and Mohammed Junaid Ali. Corresponding author - Jian Qin.

Funding: This research received no external funding.

Acknowledgments: The authors would like to thank all the personnel who were involved in the treatment of the patients.

Institutional Review Board Statement: This study was approved by the Institutional Review Board of Nanjing First Hospital.

Informed Consent Statement: Written informed consent was obtained from all the subjects involved in the study.

Data availability Statement: The data presented in this study are available upon request from the corresponding author.

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